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The Impact of Greenhouse Gas Risks on Stock Market Returns: An Application on G7 Countries [1]

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Abstract

This study investigates the impact of greenhouse gas risks on stock market returns. While carbon dioxide, methane, and nitrogen gas emissions are taken as greenhouse gases; the stock market benchmark indices of the G7 countries, which are defined as the seven most developed countries in the world, are taken as the basis for the stock market. Due to data limitations, the scope of the current study has been set as the 2000-2020 time period and the panel data analysis method has been applied. In this study, endogeneity and multicollinearity problems, cross-sectional dependence, and homogeneity/heterogeneity tests are tested respectively, and the model is estimated by performing unit root analysis in line with the findings obtained. The results of the analyses indicate that there are no endogeneity and multicollinearity problems among the variables used in the study, there is cross-sectional dependence, the variables are stationary at level I(0), there are problems of autocorrelation in the panel and it is appropriate to estimate the model with the fixed effects model. As a result of the estimation with the robust model estimator that solves the problem of autocorrelation, it is found that carbon dioxide and methane have a negative effect on stock market return, while nitrogen gas has a positive effect on stock market return. These findings suggest that investors reflect their concerns about climate change to stock markets through greenhouse gas emissions.

Keywords: *Stock Market Returns, Greenhouse Gas, Panel Data Analysis*

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[1] This study does not require ethics committee permission.

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Sera Gazı Risklerinin Pay Piyasası Getirisine Etkisi: G7 Ülkeleri Üzerine Bir Uygulama

Erol KÖYCÜ [3]

Başvuru Tarihi: 24.07.2024 **Kabul Tarihi:** 18.11.2024 **Makale Türü:** Araştırma Makalesi

Öz

Bu çalışmada sera gazı risklerinin pay piyasa getirisine etkisi araştırılmıştır. Sera gazı olarak karbondioksit, metan ve azot gazı salınımları alınırken; pay piyasası olarak dünyanın en gelişmiş yedi ülkesi olarak ifade edilen G7 ülkeleri pay piyasası gösterge endeksleri baz alınmıştır. Veri kısıtı dolayısıyla çalışmanın kapsamı 2000-2020 dönem aralığı olarak belirlenmiş ve panel veri analiz yöntemi uygulanmıştır. Çalışmada sırasıyla içsellik ve çoklu doğrusallık sorunları, yatay kesit bağımlılığı ve homojenlik/heterojenlik testleri sınanmış, elde edilen bulgular doğrultusunda birim kök analizi yapılarak model tahmini gerçekleştirilmiştir. Yapılan analizler sonucunda çalışmada kullanılan değişkenler arasında içsellik ve çoklu doğrusal bağlantı sorunlarının olmadığı, yatay kesit bağımlılığının olduğu, değişkenlerin düzeyde durağan olduğu I(0), panelde otokorelasyon sorununun olduğu ve tahmin edilecek modelde sabit etkiler modeli ile tahminleme yapmanın uygun olduğu tespit edilmiştir. Otokorelasyon sorununu çözen dirençli model tahmincisi ile yapılan tahminleme sonucunda karbondioksit ve metan gazının pay piyasa getirisini negatif yönde etkilediği, azot gazının ise pay piyasa getirisini pozitif yönde etkilediği tespit edilmiştir. Bu bulgular, yatırımcıların iklim değişikliğine ilişkin endişelerini sera gazı emisyonları aracılığıyla hisse senedi piyasalarına yansıttıklarını göstermektedir.

Anahtar Kelimeler: *Pay Piyasa Getirisi, Sera Gazı, Panel Veri Analizi*

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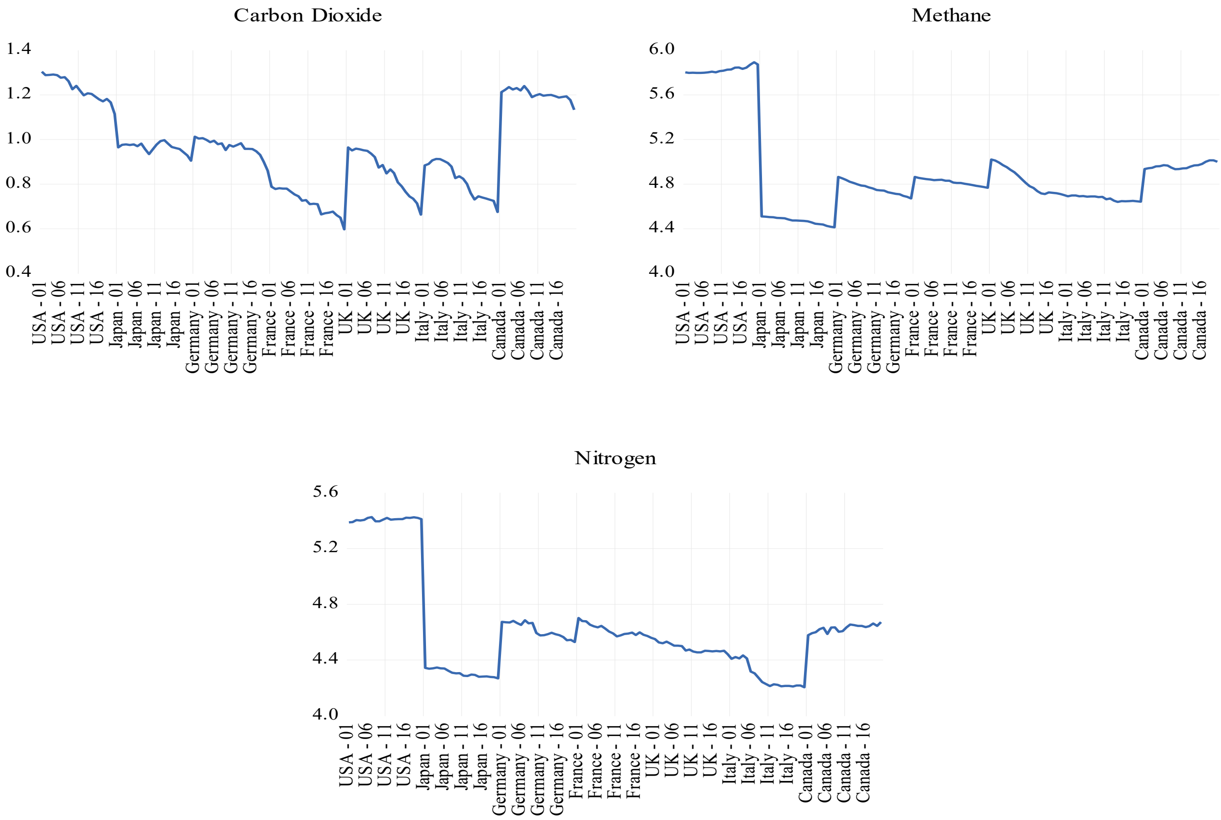
Introduction

Climate change is an issue that closely concerns almost all segments of the global conjuncture. In fact, due to climate change, sea surface temperatures are reaching record highs, average seasonal temperatures are rising, polar ice caps are melting rapidly, natural disasters such as floods, fires, and droughts are occurring more frequently, and as a result of all these, it can be said that disruptions in the ecological balance have occurred. On the other hand, events are organized to draw attention to and combat climate change. In this context, the COP28 conference organized by the United Nations in 2023 was held in Dubai, United Arab Emirates (www.cop28.com). At the end of the conference, all countries were called to 'move away from fossil fuels' (www.bmj.com). However, the Paris Agreement, accepted in 2015, covers the reduction, regulation, and financing of greenhouse gas emissions and aims to keep the global temperature increase below 1.5 Celsius (www.unfccc.int). In addition, it can be said that within the scope of combating climate change, many countries have implemented regulations on emissions and have taken constructive steps to reduce greenhouse gas emissions (The GGP, 2004, p. 3).

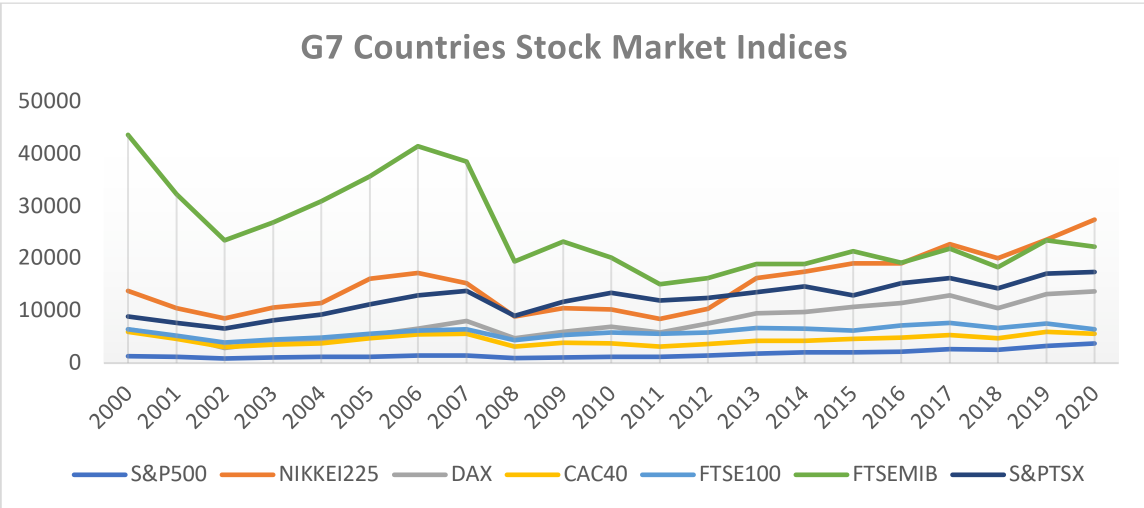
Greenhouse gases, which are also the subject of the present study, are divided into three: carbon dioxide, methane, and nitrogen. Increased greenhouse gas emissions are expected to have a negative impact on people, nature, and plants. In other words, it can be stated that there is an adverse relationship between increasing greenhouse gas emissions and ecological balance. According to the IPCC (The Intergovernmental Panel on Climate Change) 2020 report, global warming due to emissions from human activities has increased unprecedentedly in recent years. According to the same report, the three countries with the highest global emissions are China (26.9%), USA (12.2%) and India (7.3%). This result can be explained by taking into account the shares of these countries in the world economy, their economic size, and population ratios. Therefore, it can be concluded that the economic size, growth capacity, and population ratios of countries are closely related to their greenhouse gas emissions. In addition, the measures taken, steps taken, and incentives provided by countries for climate change are also thought to affect greenhouse gas emissions. In order to have more detailed information about the emissions of the countries analyzed in the current research, Graph 1 below has been prepared.



Graph 1. Greenhouse Gases Emissions

As can be seen from the graphs above, the country with the highest emissions among the countries analyzed in the study is the USA. At the same time, Canada has higher emissions of carbon dioxide, methane, and nitrogen emissions compared to other countries. On the other hand, it can be interpreted that there has been a downward trend in the emissions of countries over the years. Therefore, it can be said that the emissions of countries differ depending on their economic, social, and human factors. This situation may affect investments in countries, in other words, investor behavior. In fact, investors are expected to invest more in environmentally sensitive projects and in countries/companies that fight against climate change (Bollen, 2007, p. 683). In this way, investments will be made within the framework of social responsibility and companies that fight against climate change will be supported. Green bonds, sustainable bonds, renewable energy funds, and clean energy funds, which have been offered to investors as new investment instruments in recent years, are the main examples in this regard. In addition, in recent years, corporate companies have declared that they will use the financing obtained during the borrowing phase for renewable energy investments. It can be interpreted that such companies take socially sensitive steps. Therefore, it can be concluded that increases in greenhouse gas emissions may adversely affect the investments made, cause a decline in investor risk appetite, and a sell-off in financial markets.

Many investment instruments can be invested in financial markets. These include stocks, government debt instruments, funds, and private-sector debt instruments. Graph 2 below shows the time path graphs of the stock markets of the countries analyzed in the current research based on the 2000-2020 period range.



Graph 2. Stock Market Indices

Within the scope of the study, S&P500 for the USA, NIKKEI225 for Japan, DAX for Germany, CAC40 for France, FTSE100 for the UK, FTSEMIB for Italy, and S&PTSX for Canada are taken as benchmark indices. As can be seen from the graph above, all of the stock markets analyzed within the scope of the study experienced a break in 2008. It is thought that the global crisis of the same year was influential in this breakdown and had a negative impact on investor risk appetite. However, it can be interpreted that a general recovery trend started after 2008 and stock markets have been on the rise over the years. If it is remembered that the emissions of the same countries have been decreasing over the years, it can be interpreted that this situation affects the stock market positively in the first place and that there may be a negative correlation between them.

Based on the information provided above, this study investigates the relationship between greenhouse gas emissions and the stock market. For this purpose, carbon dioxide, methane, and nitrogen gas are taken as greenhouse gases, while the stock market benchmark indices of the G7 are taken as stock markets. Due to data limitations, the scope of the study has been defined as the 2000-2020 period and the panel data analysis method was applied. It is thought that it is important to examine and investigate environmental pollution, which has an increasing impact on the investments made, in this respect. In the literature, there is a generally negative relationship between emissions and stock markets (Chang et al, 2020, p. 1; Hlavackova, 2022, p. 2; Salehi et al., 2022, p. 10; Sakın and Kefe, 2023, p. 39), but contrary results have also been obtained (Wang et al, 2014, p. 505; Noh and Park, 2023, p. 58; Aharon et al., 2024, p. 1). Therefore, it can be stated that field studies continue in the literature. In this context, it is thought that the current research will contribute to the development of the literature and provide useful information.

Literature Review

The impact of recent climate change-induced natural events on returns is a topic of close interest to investors and researchers. In the literature, there are many different studies conducted from the perspective of this issue (Cooley, 2012, p. 97; Venturini, 2022, p. 1; Antoniuk and Leirvik, 2024, p. 42). As can be seen from the studies in the literature, it can be said that the current issue continues to be discussed and no definite conclusion has been reached.

According to the stakeholder theory, which is evaluated in the context of corporate social responsibility, company managers try to maximize the interests of all stakeholders of the company (Freeman, 1984; Smith, 2015, p. 77). For this purpose, it is predicted to improve relations with external groups and thus strengthen the company's competitive advantage (Wilson, 2003, p. 1-5). Another assumption of this theory is that the economic, social, and ethical issues of companies are not independent of each other (Mosca and Civera, 2017, p. 16). Therefore, when developing policies, companies are expected to give importance to projects that are compatible with ethical values, in other words, environmentally sensitive projects. In this context, it can be said that companies that fight against climate change are perceived positively by investors, while companies that act in the opposite direction evoke a negative perception among investors. According to the Whittaker (2000) study in the literature, it is stated that the shares of companies that develop projects sensitive to climate change and take proactive measures in this regard outperform their competitors in the stock market. Bringing a different perspective to the literature, Cao and Wei (2005) investigated the relationship between stock returns and temperature values. The study was conducted for the period between July 3, 1962 and July 9, 2001 and for eight different countries, namely the USA, Germany, UK, Sweden, Canada, Australia, Taiwan, and Japan. As a result of the study, a statistically significant (negative correlation) was found between stock returns and temperature values. In other words, an increase in temperature values has a negative impact on stock returns. In another study introduced to the literature, Ziegler et al. (2011) investigated the impact of corporate responses to climate change on US and European stock market performances. The study is based on the 2001-2006 period and the CAPM model and the Carhart 4-factor model are applied. As a result of the study, it was found that the strategy of buying the stocks of companies that make climate change response statements and selling the stocks of companies that do not make a response statement is more significant in the European stock market.

Vlady (2015), who investigated the impact of climate change on the stock market, analyzed the Australian S&P/ASX 200 index between the period 07-1992 and 07-2006. The analysis indicates that investors are affected by climate change, but their stock performances are affected differently. In another study investigating the impact of corporate disclosures on stock prices in the context of climate change Liesen et al. (2017), examined 433 companies operating in Europe over the period 2005-2009. As a result of the study, it was determined that investors do not ignore companies' carbon emission disclosures when making investment decisions and corporate disclosures have an impact on stock prices. In another study in the literature Jiang and Weng (2020), investigated the impact of climate change risk on companies operating in the agricultural sector. The study finds that climate change risk has a significant impact on the profits of companies operating in the agricultural sector. Another study examining the relationship between climate change and the stock market was brought to the literature by Faccini et al. (2021). The study investigates whether climate change news affects stock prices in the 2000-2018 period for the USA. At the end of the study, it was found that the climate policy factor affected the US stock market and this effect was most pronounced in the 2012-2018 period. However, Pagnottoni et al. (2022) who bring a different perspective to the literature and investigate the impact of natural events on stock markets as a result of climate change, examined 27 international stock markets based on the period between February 8, 2001 and December 31, 2019. As a result of the analysis, it was found that the reactions of stock markets to natural events differed regionally; however, stock markets in the European region were more sensitive to natural events. In another recent study, Barbera-Marine et al. (2023) examined the impact of climate change risk on stock returns. In the study, 265 companies in the Stoxx 600 index for the period 2015-2021 were analyzed and the panel data analysis method was used. According to the findings, carbon emissions have a negative impact on stock returns. On the other hand, companies with a good rating on environmental sensitivity have been found to have a positive impact on corporate returns as a result of this rating. In another recent study Li et al. (2024), investigated the impact of climate change on the NASDAQ 100 index. As a result of the study, which analyzed 526 climate events that occurred in the US in the 2000-2019 period, it was determined that climate change had an impact on the NASDAQ 100 index. However, it is concluded that the NASDAQ 100 index is affected differently depending on the climatic events.

As can be seen from the studies in the literature, the relationship between climate change and stock returns has been analyzed by different researchers in different scopes over the years. While some of these studies have attempted to measure climate change based on climate events, others have been included in the framework of emission releases. In this context, it can be said that the current issue has attracted the attention of researchers and continues to be discussed in the literature over the years. However, it is thought that the differences in the findings may be due to the scope and period ranges of the studies. From this point of view, it is thought that the current research will contribute to the ongoing literature studies and provide useful information for the development of the literature.

Methodology

Dataset and Variables

In the current study investigating the impact of greenhouse gas risks on stock market returns, data for the G7 countries are analyzed for the period 2000-2020. The emissions of these countries were obtained from the World Bank's official website (data.worldbank.org), and the stock market benchmark indices of the same countries were obtained from www.investing.com. The variables used as the basis for greenhouse gas emissions and stock market benchmark indices are shown in Table 1 below;

Table 1
Variables Using in the Research

Dependent Variables			Calculation Method
	Country	**Index**	
Stock Market Benchmark Indices	USA	S&P500	Logarithmic Return
	Japan	NIKKEI225	
	Germany	DAX	$\text{Ln}\left(\frac{P_t}{P_{t-1}}\right)$
	France	CAC40	
	UK	FTSE100	
	Italy	FTSE MIB	
	Canada	S&PTSX	
Independent Variable			
	Indicator	**Description**	
Greenhouse Gas Emissions	Co2	C_O2 emiss. met. tons per capita	Logarithm
	CH_4	Methane emiss. kt of C_O2 equ.	
	N_2O	Nitrogen oxide emiss. thousand met. tons of C_O2 equ.	$\text{Ln}(P_t)$

The dependent variable of the current study is the stock market benchmark indices of the countries analyzed, while the independent variables are greenhouse gas emissions. Since the subject of the study is 'the impact of greenhouse gas risks on stock market returns', in this context, logarithmic continuous returns of stock market benchmark indices and natural logarithms of greenhouse gas emissions are taken. Thus, all variable units were reduced to the same level and made ready for analysis.

Developed Models and Hypotheses

The model developed for the current study to determine the impact of greenhouse gas risks on stock market return is as follows;

$$RETURN_{it} = \beta_{1it} + \beta_{2it}Co2_{it} + \beta_{3it}CH4_{it} + \beta_{4it}N2O_{it} + \varepsilon_{it} \qquad (1)$$

In the regression equation above, RETURN is the dependent variable while Co2, CH_4, and N_2O are the independent variables. In addition, β_{1it} represents the constant coefficient, β_{2it}, β_{3it} and β_{4it} represent the slope of the independent variables and finally ε_{it} represents the error term of the model (Mátyás and Sevestre, 1996, p. 27). In line with the model developed above, three different hypotheses were tested in the current study. Information on the tested hypotheses is presented in Table 2 below;

Table 2
Developed Hypotheses

Hypotheses	Description
The 1st Hypothesis	H_0: No relationship between RETURN and Co2
The 2nd Hypothesis	H_0: No relationship between RETURN and CH_4
The 3rd Hypothesis	H_0: No relationship between RETURN and N_2O

The table above shows the hypotheses tested in the current study. The 1st Hypothesis tests the relationship between RETURN and Co2, the 2nd Hypothesis tests the relationship between RETURN and CH_4, and finally, the 3rd Hypothesis tests the relationship between RETURN and N_2O. Increased carbon dioxide emissions have a negative impact on climate change. In this context, it is expected that an increase in carbon dioxide emissions will negatively affect the stock market return, considering that rational investors invest for the future. However, the increase in methane gas increases global temperature values. With the increase in temperature values, deterioration in ecological balance is observed and climate change is negatively affected. Therefore, an increase in methane gas emissions is expected to have a negative impact on stock market return. In case of excess nitrogen gas emissions, which are not as harmful as carbon dioxide and methane gas, plants are adversely affected. Considering factors such as premature aging of plants, slowing of plant metabolism, and late ripening of fruits, this has a negative impact on climate change, which in turn is expected to increase nitrogen gas emissions and negatively affect stock market returns.

Analysis Method

In this study, the impact of greenhouse gas risks on stock market returns is examined using the panel data analysis method. In this respect, EViews12 and Gauss23 statistical programs were used for econometric analysis. In order to obtain consistent and reliable results in the panel data analysis method, firstly, cross-sectional dependence should be tested. Then, depending on the received results, the optimal unit root test should be tested, and model estimation, autocorrelation, and variance assumptions should be tested. Finally, an estimation should be made according to the general results obtained.

Remembering that the time dimension of the current study is 20 (t; 20) and the cross-sectional dimension is 8 (n; 8), in other words, the LM test developed by Breusch and Pagan (1980) has been used to test for cross-sectional dependence since the n dimension is smaller than the t dimension. The regression formula of the test is shown in equation 2 below;

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \hat{\rho}_{ij}^{2} \rightarrow x^{2} \frac{N(N-1)}{2} \qquad (2)$$

In the above equation, n; cross-sectional dimension, t; time dimension, and $\hat{\rho}_{ij}$ refers to the correlation coefficients of the residuals obtained from the model. In line with the analysis, cross-sectional dependence has been detected among the variables used in the study. It is recommended to use 2nd generation stationarity tests in studies where cross-sectional dependence is detected (Choi, 2002, p. 13-14; Phillips and Sul, 2003, p. 218; Topaloglu, 2018, p. 23).

For the research unit root test, two different 2nd generation unit root tests have been tested. These are the PANIC test developed by J. Bai and S. NG (2004) and the CIPS test introduced by Pesaran (2007). In this context, the regression equation of the CIPS test used in the current study is as follows;

$$\mathrm{CIPS} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{CADF}_{\mathrm{i}} \qquad (3)$$

The CIPS test above is a null hypothesis test. In other words, the null hypothesis of the test states that the series are non-stationary (H_0: $\pi=1$), while the alternative hypothesis states the opposite (H_1: $\pi\neq1$). The regression equation of the PANIC test, another second-generation unit root test used in the study, is as follows;

$$\mathrm{P}_{\grave{e}}^{c} = \frac{-2\sum_{i=1}^{N} lnP_{\grave{e}}^{c}(i)-2N}{\sqrt{4N}} \xrightarrow{d} N(0,1) \qquad (4)$$

$$\mathrm{P}_{\grave{e}}^{T} = \frac{-2\sum_{i=1}^{N} lnP_{\grave{e}}^{T}(i)-2N}{\sqrt{4N}} \xrightarrow{d} N(0,1) \qquad (5)$$

The PANIC test in the above equation can determine whether the stationarity in the series is common, variable-specific, or both common and variable-specific (Bai and NG, 2004, p. 1127). However, the PANIC test is a null hypothesis test like the CIPS test above.

In the next stage of the current study, model estimation has been performed. F test, Breuch-Pagan LM (1980) test, and Honda (1985) test are used to determine which of the fixed effects model and random effects model is valid in model estimation. In addition, the estimated model is tested for heteroscedasticity using the Breusch-Pagan-Godfrey LM test and for autocorrelation using the Baltagi ve Li (1991) and Born and Breitung (2016) tests.

Findings and Discussion

In this part of the current research, the findings obtained are in line with the statistical process described above, and the interpretations of these findings are presented. However, before proceeding to these findings, descriptive statistics results are presented to see the structure of the data set, and correlation analysis results are presented to test for endogeneity and multicollinearity problems. In this context, the descriptive statistical information tested first is given in Table 3 following;

Table 3
Descriptive Statistics

	RETURN	**Co2**	**CH_4**	**N_2O**
Mean	0.007506	0.964898	4.905795	4.619551
Med.	0.031699	0.957527	4.798235	4.577790
Max.	0.195124	1.304739	5.894591	5.426824
Min.	-0.296926	0.597002	4.411339	4.203839
Std. Dev.	0.088979	0.187637	0.406551	0.354175
Skew.	-1.121048	0.149152	1.450513	1.345911
Kurto.	4.145679	1.963212	4.041493	3.865509
Jarque-Bera stat.	36.98087***	6.789505**	55.42052***	46.63758***
Obser.	140	140	140	140

***, **, and * indicate respectively statistical significance at the 1, 5, and 10 percent levels.

Descriptive statistics results are given in Table 3. As seen in the table, the average stock market return in the G7 countries is 0.007, while the Co2 average is 0.96, the CH_4 average is 4.90, and the N_2O average is 4.61. On the other hand, Jargue-Bera statistic values show that the probability values of all variables are smaller than the critical values. In other words, It has been detected that the variables used in the study do not show normal distribution characteristics. In addition, it can be stated that the study dataset consists of 140 observations.

In the next stage of the study, correlation analysis is performed to detect endogeneity and multicollinearity problems. Since it was determined that the variables used in the study did not show normal distribution, the Spearman correlation test has been used in the analysis of correlation. Findings are given in Table 4 below;

Table 4
Correlation Analysis

Correlation T-stat. Prob.	RESIDUAL SERIES	Co2	CH_4	N_2O
RESIDUAL SERIES	1.000000			

Co2	0.010724	1.000000		
	0.125981	-----		
	0.8999	-----		
CH_4	-0.029695	0.540968	1.000000	
	-0.348996	7.556012	-----	
	0.7276	0.0000	-----	
N_2O	-0.007903	0.556957	0.869318	1.000000
	-0.092839	7.877709	20.66187	-----
	0.9262	0.0000	0.0000	-----

The endogeneity problem refers to the high correlation between the model error term and the independent variables. In other words, a correlation of +/- 0.90 and above (p>0.90 or p<-0.90) between the model error term and the independent variables indicates an endogeneity problem (Tabachnick and Fidell, 2001, p. 309). In this context, the results of the analysis show the highest correlation between the model error term and CH_4. In other words, the correlation coefficient between residual series and CH_4 is -0.02. Therefore, it can be said that there is no endogeneity problem in the study.

The multicollinearity problem refers to the high correlation between independent variables. In other words, a correlation of +/- 0.90 and above (p>0.90 or p<-0.90) between independent variables indicates the problem of multicollinearity (Kim, 2019, p. 560). In this context, the results of the analysis show that the highest correlation between the independent variables is found between CH_4 and N_2O. In other words, the correlation coefficient between CH_4 and N_2O is 0.86. Therefore, according to the correlation analysis results it can be stated that there is no multicollinearity problem in the study. Another test for multicollinearity problems is the Variance Inflation Factors (VIF) test. The test results are given in Table 5 below;

Table 5
Results of the VIF test

Variable	Coefficient Variance	Uncentered VIF	Centered VIF	Tolerance Values
Co2	0.038277	1.250130	1.249661	0.800217
CH_4	0.009553	1.261565	1.258987	0.794289
N_2O	0.001033	178.6880	1.011169	0.988954

Another test for the multicollinearity problem is the VIF test. If the centered VIF values are greater than 5 or the tolerance values are less than 0.20, it can be stated that there is a multicollinearity problem in the study (Menard, 1995, p. 66). In light of this information, the VIF test results in Table 5 above show that the centered

VIF values are less than 5 and the tolerance values are greater than 0.20. Therefore, according to the VIF test results, it is concluded that there is no multicollinearity problem in the study. These results are similar to the correlation results.

In the next stage of the analysis process, cross-sectional dependence has been tested. The results obtained on model and variable basis are presented in Table 6 below;

Table 6
Results from the cross-sectional dependence tests

Panel A: Results for Model								
Test			stat.			prob.		
LM			320.657			0.000		
CDlm			46.238			0.000		
CD			17.880			0.000		
Panel B: Results for Variables								
Variables	LM		CDlm		CD		LMadj	
	stat.	prob	stat.	prob	stat.	prob	stat.	prob
Return	321.959	0.000	46.439	0.000	17.919	0.000	46.254	0.000
Co2	299.840	0.000	43.025	0.000	17.028	0.000	42.841	0.000
CH_4	322.459	0.000	46.516	0.000	2.188	0.028	46.331	0.000
N_2O	255.909	0.000	36.247	0.000	3.064	0.002	36.063	0.000

Panel-A section of the above table presents model-based cross-section dependence test results, while Panel-B section presents variable-based cross-section dependence test results. Since the n dimension of the current study is smaller than the t dimension, the Breusch and Pagan LM (1980) test is used as the basis for the cross-sectional dependence test. In this context, the model-based results shown in Panel-A show that the probability value of the Breusch and Pagan LM test is less than the critical value of 0.05. In other words, in this study, cross-sectional dependence can be mentioned on a model basis. However, the results do not change in the other tests tested on a model basis, and according to Pesaran scaled LM and Pesaran CD tests, cross-sectional dependence is detected on a model basis in the study.

On the other hand, Panel-B section, which shows the results of cross-sectional dependence tests on a variable basis, shows that based on the LM test results, the calculated probability values of all variables used in the study are below the critical value of 0.05. Therefore, it can be said that cross-sectional dependence is detected in all variables used in the study. In other words, it can be interpreted that a macroeconomic shock in one of the G7 countries affects other countries as well. However, the results do not change in the other tests tested based on variables; according to CDlm (Pesaran 2004), CD (Pesaran 2004), and LMadj (PUY, 2008) tests, cross-sectional dependence is detected based on variables in the study.

In the next step of the study, homogeneity and heterogeneity tests of the variables are performed by Pesaran and Yamagata (2008) test. The results are presented in Table 7 below;

Table 7
Results of Homogeneity/Heterogeneity Test

Variables	$\tilde{\Delta}$	Prob.	$\tilde{\Delta}_{adj}$	Prob.
Return	-1.550	0.939	-1.682	0.954
Co2	0.186	0.426	0.202	0.420
CH_4	6.158	0.000	6.680	0.000
N_2O	0.350	0.363	0.380	0.352

As can be seen from the table above, where the homogeneity/heterogeneity test results are presented on a variable basis, it is determined that the delta and adjusted delta probability values of the CH_4 variable used in the study are less than the critical value of 0.05, while the delta and adjusted delta probability values of all other variables used in the study are greater than the critical value. Based on these results, it can be concluded that the CH_4 series is heterogeneous, while the other variable series are homogeneous. Considering the results of the cross-sectional dependence and homogeneity/heterogeneity tests of the variables used in the study, unit root analyses are performed in the next stage.

1st generation unit root tests are used if no cross-sectional dependence, and 2nd generation unit root tests are used in the opposite case (Nur and Korkmaz, 2022, p. 111-113). In this context, in the current study, CIPS and PANIC tests, which are the second generation unit root tests, are used in the unit root test of the study, since cross-sectional dependence is detected. The test results obtained are shown in Table 8 below;

Table 8
Results from Unit Root Tests

Panel A: CIPS				
Variables	Constant		+ Trend	
	t-stat.	p-value	t-stat.	p-value
Return	-3.7152	<0.01	-3.8617	<0.01
Co2	-4.0541	<0.01	-3.4598	<0.01
CH_4	-3.1587	<0.01	-3.1555	<0.05
N_2O	-4.6462	<0.01	-4.5674	<0.01
Critical Values	1%	-2.61	1%	-3.17
	5%	-2.35	5%	-2.89
	10%	-2.21	10%	-2.74
Panel B: PANIC				
Variables	Constant		+ Trend	
	stat.	p-value	stat.	p-value
Return	2.5674	0.0102	2.4632	0.0137
Co2	4.7411	0.0000	2.5447	0.0109
CH_4	2.8285	0.0046	2.9639	0.0030
N_2O	12.5530	0.0000	13.3141	0.0000

Panel-A of Table 8 above shows the CIPS test results and Panel-B shows the PANIC test results. According to the CIPS test results, the t-stat. values of all variables in the two models are smaller than the 5% critical value. In other words, the calculated t-stat. values are to the left of the 5% critical values. Therefore, the H_0 hypothesis of the test is rejected and it can be said that the variables are stationary at level.

On the other hand, the results of the PANIC test show that the p-values of all variables are smaller than the 5% critical value. Therefore, the H_0 hypothesis of the test has been rejected, whereas the alternative hypothesis has not been rejected. In other words, according to PANIC test results, all variables used in the study are stationary at level, i.e. they do not contain a unit root. When the results obtained are evaluated in general terms, it can be interpreted that CIPS and PANIC tests give similar results and support each other.

To make estimations in the panel data analysis method, the series should be stationary at the level (Tekin, 2019, p. 126). Since all of the explained and explanatory variables used in the current research have been determined I(0), the model estimation is performed with the help of the F test, LM test, and Honda test in the next stage of the study. The outputs obtained as a result of the estimation are given in Table 9 following;

Table 9
Results of Estimation Model Identification Analysis

Effect	test	stat.	p-value
Fixed	Group (F test)	0.3780	0.8916
	Time (F test)	39.0968	0.0000
	Two effect (F test)	30.5545	0.0000
Random	Group (LM test)	3.2648	0.0707
	Time (LM test)	300.7126	0.0000
	Two effect (LM test)	303.9775	0.0000
Random	Group (Honda test)	-1.8069	0.9646
	Time (Honda test)	17.3410	0.0000
	Two effect (Honda test)	10.9843	0.0000

In the panel data analysis method, estimation is made with fixed effects model and random effects model approaches (Topaloglu, 2018, p. 26). In the current study, which model preferred is tested with the F test, Breuch-Pagan LM (1980), and Honda (1985) tests. Among these tests, the F test provides fixed effects model results, while the LM and Honda tests provide random effects model results. If the study data set covers a certain period range and consists of a certain scope, the fixed effects model should be preferred in the estimation modeling (Baltagi, 2005, p. 12). Since the current study covers G7 countries, i.e. a specific group of countries, and its scope is the same for each country, it is considered that the results of the fixed effects model should be taken into account in the study. Therefore, it can be concluded that the fixed effects model is valid in the model estimation. In light of this information, the results of the F test, which tests the fixed effects model, show that the time dimension is valid in the study, while the cross-sectional dimension is invalid.

Another basic assumption in the panel data analysis is that heteroscedasticity and autocorrelation. In this context, heteroscedasticity and autocorrelation test results based on the fixed effects model are presented in Table 10 below;

Table 10
Results of Diagnostic Tests

Panel A: Result for Heteroscedasticity		
test	stat.	p-value
Breusch-Pagan-Godfrey	6.1275	0.4090
Panel B: Result for Autocorrelation		
test	stat.	p-value
Baltagi and Li	6.4825	0.0108
Born and Breitung	10.1373	0.0014

Panel A of the table above presents the results of heteroscedasticity, while Panel B presents the results of autocorrelation. Breusch-Pagan-Godfrey Heteroscedasticity LM test is used to test for heteroscedasticity based on the fixed effect model, while Baltagi and Li (1991) test and Born and Breitung (2016) test are used to test for autocorrelation. The results of the test for heteroscedasticity in Panel-A show that the calculated p-value is above 0.05. In other words, the H_0 hypothesis of the test cannot be rejected and it can be stated that there is no problem of heteroscedasticity in the study. On the other hand, the results in Panel-B, where the autocorrelation test results are presented, show that the calculated p-value for both tests is below 0.05. Therefore, it can be said that the autocorrelation problem is valid in the research. In light of the results obtained, it can be concluded that there is no heteroscedasticity problem in the panel, but there is an autocorrelation problem.

In the next step of the study, model estimation is performed. At this step, estimation is made with the White panel standard error correction method, which solves the autocorrelation problems in the panel. This method solves the problem of correlation as well as different error variances across cross-sections. The estimated panel analysis results are presented below;

Table 11
Estimated model

Dep. Variable	**Method**			**Period**
RETURN	Least Squares Method - White			2000 – 2020
Indep. Variables	Coefficient	Std. Error	t-stat.	Prob.
Co2	-0.073901	0.016707	-4.423285	0.0000
CH_4	-0.055828	0.016068	-3.474528	0.0007
N_2O	0.065733	0.018261	3.599701	0.0005
C	0.053508	0.009317	5.743250	0.0000
	Weighted Statistics			
	Root MSE	0.031725	R^2	0.871958
	Mean dep. var	0.007506	Adjust. R^2	0.847881
	S.D. dep. var	0.088979	S.E. of regress.	0.034704
	Sum sq. resid	0.140910	F-statistic	36.21633
	D-Watson stat.	1.935580	Prob (F-stat.)	0.000000

Table 11 presents the results of the panel data analysis. Firstly, the prob (F-ist.) value shows that the calculated stat. is below 0.05. Therefore, it can be said that the established panel data analysis method is meaningful. If we look at the Adjusted R^2 value, which expresses how much of the changes in the explained variable are due to the explanatory variables used in the study, it is seen that the value is calculated as 84.78%. Therefore, it can be said that approximately 85% of the changes in stock market returns are caused by greenhouse gas emissions. On the other hand, the calculated Durbin-Watson value is 1.93. Since the value is close to 2, it is thought that the autocorrelation problem may have been eliminated in the estimated model. The coefficient results in the table show that all independent variables used in the study give statistically significant results. In this context, it is determined that a one-unit increase in the Co2 variable causes a 7.39% decrease in the stock market return. Considering that the increase in carbon dioxide emissions has a negative impact on climate change, it is thought that this situation negatively affects investors' risk appetite and causes them to worry about long-term investments. Therefore, the findings are in line with expectations. However, another result in the table shows that a one-unit increase in the CH_4 variable causes a decrease of 5.58% in the stock market return. In the context of climate change, methane is a dangerous greenhouse gas like carbon dioxide. Therefore, increases in methane emissions are expected to have a negative impact on stock market returns by making investors more nervous like carbon dioxide emissions. Finally, another result in the table shows that a one-unit increase in the N_2O variable causes a 6.57% increase in the stock market return. Considering that nitrogen gas is less harmful and non-toxic than carbon dioxide and methane, these results are explainable and do not affect investors' risk appetite.

When the obtained panel data analysis results are evaluated in general terms, The 1st Hypothesis (H_0: No relationship between RETURN and Co2), The 2nd Hypothesis (H_0: No relationship between RETURN and CH_4), and The 3rd Hypothesis (H_0: No relationship between RETURN and N_2O) developed in the current study are rejected and it can be said that all variables used in the study give statistically significant results. Therefore, the study concludes that greenhouse gases such as carbon dioxide, methane, and nitrogen affect stock market returns.

Conclusion

Recent climate events are the main agenda of almost every country. Because climate events directly or indirectly affect all stakeholders in the global world. The disruption of the ecological balance of nature can have many negative economic, social, and humanitarian effects on a country basis, as well as psychological and therefore social effects on an individual basis. In this context, it is seen that many countries and institutions that want to prevent climate change, do not allow the ecological balance of nature to deteriorate further, in other words, to prevent the destruction that climate change will cause in the global world, make promises and put into effect implementations related to climate change. On the other hand, financial markets are not insensitive to the issue of climate change. It is observed that companies declare that they will use the financing to be obtained while offering debt instruments in the field of green transformation or sustainable finance. Therefore, it can be said that the problem of climate change is an issue that closely concerns almost everyone in the global world.

This study investigates the impact of greenhouse gas risks, which have a major impact on climate change, on stock market returns. For this purpose, carbon dioxide, methane, and nitrogen gas emissions are taken as greenhouse gases, while the stock market benchmark indices of the G7 countries, which are considered the seven most developed countries of the world, are taken as the stock market benchmark indices. Due to data limitations, the scope of the study has been determined as the 2000-2020 period and the panel data analysis method has been applied. In this context, in the analysis process of the current study, descriptive statistics information was first given to see the structure of the data set, and then correlation analysis and VIF test were performed to test the endogeneity and multicollinearity problems between variables. Within the framework of the panel data analysis method, cross-sectional dependence with the LM test developed by Breusch and Pagan (1980), unit root test with the CIPS test developed by Pesaran (2007) and PANIC test developed by Bai and NG (2004), estimation model test with the F test, Breuch-Pagan LM test (1980) and Honda test(1985), panel heteroscedasticity test with the LM test developed by Breusch-Pagan-Godfrey and finally autocorrelation test with the developed by Baltagi and Li (1991) and Born and Breitung (2016) tests have been tested. At the end of this econometric process, estimation is performed with the White panel standard error correction method, which solves the autocorrelation problems in the panel.

According to the estimation results, a one-unit increase in the Co2 variable causes a 7.39% decrease in the stock market return; a one-unit increase in the CH_4 variable causes a 5.58% decrease in the stock market return; and a one-unit increase in the N_2O variable causes a 6.57% increase in the stock market return. Based on these results, it can be stated that carbon dioxide and methane gas emissions have a negative effect on stock market return, while nitrogen gas emissions have a positive effect. Considering that carbon dioxide and methane gas damage the ecological balance in the fight against climate change, these gases are thought to have a negative impact on the risk appetite of long-term investors and thus negatively affect the stock market return. Therefore, this is an expected result. However, the positive effect of nitrogen gas on stock market return is an important finding of the study. However, it is seen that similar results are obtained in the studies conducted in the literature specific to nitrogen gas. For example, Bui et al. (2023) recently found that gross fixed capital, services, and trade openness positively affect nitrogen emissions. In an environment where both capital flows and trade relations increase, companies' cash flows and debt repayment periods will be positively affected. Therefore, an increase in economic activity increases nitrogen emission, and nitrogen emission indirectly affects the financial performance of companies positively with the increase in economic activity. In light of this information, the positive effect of nitrogen emissions on stock returns can be explained. On the other hand, in another study in the literature, Yusuf et al. (2020) similarly found that nitrogen gas positively affects economic growth, but did not obtain statistically significant results. Moreover, considering that carbon dioxide and methane gas emissions have a significant impact on climate change, while nitrogen gas emissions are less harmful compared to carbon dioxide and methane, the findings can be explained in terms of harmful gas emissions. These findings suggest that investors reflect their concerns about climate change to stock markets through greenhouse gas emissions. In this context, it's thought that investors behave rationally and respond meaningfully to harmful gas emissions. The findings obtained are similar to the studies in the literature such as Chang et al, 2020; Hlavackova, 2022; Salehi et al., 2022; Sakın and Kefe, 2023.

Finally, the present study offers some recommendations for country managers and investors. In this context, country leaders should fight climate change to accelerate the flow of funds into their countries' financial markets and to provide external funding to companies. In this context, it is recommended that countries pay attention to greenhouse gas emissions, reduce harmful gas emissions, and enact positive implementations within the scope of combating climate change. In this context, it is recommended to provide tax incentives for companies that reduce greenhouse gas emissions, to encourage companies that achieve their greenhouse gas targets by giving them awards in the field of sustainable finance, and to provide support to companies for renewable energy. In addition, it is recommended that investors who will make long-term investments in financial markets should consider the emissions of the relevant company as well as its financial ratios when selecting companies for portfolio construction. The fact that the company to be invested in has low emissions or uses renewable energy rather than fossil fuels in its operations is considered to be in favor of the investor in the long run. In this way, investors will both make their investments within the framework of social responsibility and reward companies that tackle the climate crisis.

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Genişletilmiş Özet

Amaç

Bu çalışmada sera gazı risklerinin pay piyasa getirisine etkisi araştırılmıştır. Sera gazı olarak karbondioksit, metan ve azot gazı salınımları alınırken; pay piyasası olarak dünyanın en gelişmiş yedi ülkesi olarak ifade edilen G7 ülkelerinin (ABD, Japonya, Almanya, Fransa, İngiltere, İtalya ve Kanada) pay piyasası gösterge endeksleri baz alınmıştır. İklim değişikliği uzun vadede ekolojik dengeyi kalıcı olarak bozmaktadır. İklim değişikliğine neden olan başlıca faktörler ise sera gazlarıdır. Buradan hareketle sera gazlarının pay piyasasına yapılan uzun vadeli yatırımlar üzerindeki etkisinin araştırılması gerek alan yazını gerek karar vericiler gerekse yatırımcılar için önemli olduğu düşünülmektedir. Dolayısıyla mevcut çalışmada 'sera gazları ile pay piyasa getirisi arasında nasıl bir ilişki olduğu' sorusuna cevap aranmaktadır.

Tasarım ve Yöntem

Bu çalışma nicel araştırma deseni kapsamında bir araştırma makalesi olup, ekonometrik uygulamalar içermektedir. Mevcut çalışmada hem zaman boyutunun hem de kesit boyutunun olmasından hareketle panel veri analiz yöntemi uygulanmış ve veri kısıtı dolayısıyla çalışmanın kapsamı 2000-2020 dönem aralığı olarak belirlenmiştir. Çalışmanın bağımlı değişkeni olan G7 ülkeleri pay piyasası gösterge endeksleri www.investing.com adresinden; bağımsız değişkenleri olan aynı ülkelerin sera gazı emisyon salınımları ise Dünya Bankası resmî sitesinden (data.worldbank.org) alınmıştır. Değişkenlerin analize dahil edilebilmesi için pay piyasası gösterge endekslerinin logaritmik sürekli getirileri, sera gazı emisyonlarının ise doğal logaritmaları alınmıştır. Böylelikle tüm değişken birimleri aynı düzeye indirgenmiş ve analize hazır hale getirilmiştir. Analizler EViews12 ile Gauss23 istatistik programları yardımıyla gerçekleştirilmiştir. Panel veri analizi kapsamında sırasıyla spearman korelasyon analizi ve VIF testiyle içsellik ve çoklu doğrusal bağlantı sorunları test edilmiş, LM (Breusch and Pagan, 1980) testiyle gerek model bazında gerekse kesit bazında yatay kesit bağımlılığı sınanmış, elde edilen bulgular doğrultunda Bai and NG (2004) tarafından geliştirilen PANIC (Panel Analysis of Nonstationarity in Idiosyncratic and Common components) ve Pesaran (2007) tarafından geliştirilen CIPS (Cross-Sectionally Augmented IPS) testleriyle birim kök analizleri gerçekleştirilmiş, F, LM ve Honda testleriyle model tahminlemesi yapılmış ve tahmin edilen modelin Breusch-Pagan-Godfrey testiyle değişen varyans ve Baltagi ve Li (1991) ve Born ve Breitung (2016) testleriyle otokorelasyon sınamaları gerçekleştirilmiştir. Çalışmada otokorelasyon sorununun tespit edilmesinden hareketle panelde otokorelasyon sorununu çözen White dirençli tahminci ile tahminleme yapılmıştır.

Bulgular

Mevcut çalışma özelinde gerçekleştirilen ekonometrik analizler sonucunda çalışmada içsellik ve çoklu doğrusal bağlantı sorunlarının olmadığı, gerek model bazında gerekse kesit bazında yatay kesit bağımlılığının tespit edildiği, değişkenlerin düzeyde durağan yani birim kök içermediği I(0), çalışmada sabit etkili modelin geçerli olmak birlikte otokorelasyon sorununun tespit edildiği görülmektedir. Bu bağlamda panelde otokorelasyon sorununu çözen White dirençli tahminci ile yapılan tahminleme sonucunda; olasılık (F-ist.) değerinin 0.0000 olduğu, bir diğer deyişle kurulan modelin anlamlı olduğu, düzeltilmiş R^2 değerinin %84.7881 olduğu, bir diğer ifadeyle pay piyasa getirisindeki değişimlerin yaklaşık %85'inin sera gazı emisyonlarından kaynaklandığı tespit edilmiştir. Bununla birlikte çalışma sorusu olan 'sera gazları ile pay piyasa getirisi arasında nasıl bir ilişki olduğu' sorusunu cevaplamak adına katsayı sonuçlarına bakıldığında ise Co2 değişkeninde yaşanacak bir birimlik artışın pay piyasa getirisinde %7.39'luk bir azalışa neden olduğu; CH_4 değişkeninde yaşanacak bir birimlik artışın pay piyasa getirisinde %5.58'lik bir azalışa neden olduğu ve N_2O değişkeninde yaşanacak bir birimlik artışın pay piyasa getirisinde %6.57'lik bir artışa neden olduğu tespit edilmiştir. Elde edilen bu sonuçlardan hareketle karbondioksit ve metan gazı salınımlarının pay piyasa getirisini negatif yönde etkilediği, buna karşın azot gazı salınımının ise pay piyasa getirisini pozitif yönde etkilediği söylenebilmektedir.

Sınırlılıklar

Mevcut çalışmada pay piyasası olarak G7 ülkeleri pay piyasası gösterge endeksleri, sera gazı emisyonları olarak ise karbondioksit, metan ve azot gazı tercih edilmiştir. Bununla birlikte veri kısıtı nedeniyle çalışmanın kapsamı 2000-2020 dönem aralığı olarak belirlenmiştir.

Öneriler

Mevcut çalışmada ülke yöneticileri ve yatırımcılar için birtakım öneriler sunulmaktadır. Bu bağlamda ülke yöneticileri, ülkelerinin finansal piyasalarına fon akışını hızlandırmak ve şirketlere dışarıdan kaynak tesis etmek için iklim değişikliği ile mücadele etmelidirler. Bu bağlamında ülke sera gazı emisyonlarına dikkat etmeleri, zararlı gaz salınımlarını azaltmaları ve iklim değişikliği ile mücadele kapsamında pozitif uygulamaları yürürlüğe koymaları önerilmektedir. Bu kapsamda sera gazı emisyonlarını azaltan şirketlere vergi teşvikinin sağlanması, sera gazı hedeflerine ulaşan şirketlere sürdürülebilir finans alanında ödüllerin verilmesiyle cesaretlendirilmesi ve yenilenebilir enerji kullanımı için şirketlere destek sağlanması önerilmektedir. Bununla birlikte finansal piyasalarda uzun vadeli yatırım yapacak olan yatırımcıların portföy oluştururken şirket seçiminde finansal oranlar kadar ilgili şirketin emisyon salınımlarını da göz önünde bulundurmaları önerilmektedir. Yatırım yapılacak olan şirketin emisyon salınımının düşük olması ya da ilgili şirketin faaliyetlerinde fosil yakıtlardan ziyade yenilenebilir enerji kullanması, uzun vadede yatırımcı lehine olduğu düşünülmektedir.

Özgün Değer

Literatürde emisyon salınımları ile pay piyasaları arasında genel olarak negatif bir ilişkinin olduğu tespit edilmekte birlikte (Chang et al, 2020; Hlavackova, 2022; Salehi et al., 2022; Sakın ve Kefe, 2023), aksi yönde sonuçların elde edildiği de görülmektedir (Wang et al, 2014; Noh and Park, 2023; Aharon et al., 2024). Dolayısıyla literatürde alan çalışmalarının devam ettiği söylenebilmektedir. Bu bakımdan mevcut çalışmanın literatüre katkı sağlayıp, alan yazınının geliştirilmesine faydalı bilgiler sunacağı düşünülmektedir. Bununla birlikte çalışmanın G7 ülkelerine odaklanması, çalışma veri setinin pay piyasası gösterge endeksleri ile karbondioksit, metan ve azot gazı salınımlarından oluşması, çalışmayı alan yazınında yer alan diğer çalışmalardan ayrıştırmaktadır.

Araştırmacı Katkısı: Erol KÖYCÜ (%100).